Overview of Goals and Options

E. Gluskin

Outline

- Goals and Approach
- Options
- Storage Ring Upgrade
- ERL Source
- R&D

Machine Advisory Committee Meeting

November 15, 2006

Agenda

Wednesday, November 15, 2006 - Conference Room A5000, Building 401		
08:00	Committee Executive Session	V. Suller
08:30	Welcome	D. Joyce
08:35	Introduction	M. Gibson
09:00	Overview of Goals and Options	E. Gluskin
09:30	ERL Parameter Review and Physics Issues	M. Borland
10:30	Break	
10:45	ERL Integration: Outfield Option	G. Decker
11:05	ERL Integration: Infield Option	N. Sereno
11:25	Greenfield ERL and Option Comparisons	M. Borland
11:45	ERL RF Systems	A. Nassiri
12:15	Executive Session (box lunches available)	
13:00	Overview of APS SR Upgrade Options	L. Emery
13:25	1-nm Lattice Design	A. Xiao
13:50	APS x 3 Lattice Design	V. Sajaev
14:15	Booster Upgrade Requirements and Possibilities	N. Sereno
14:35	Instability Estimates	Y. Chae
15:00	Break	
15:15	APS Upgrade Installation Plan and Schedule	J. Noonan
15:30	Short X-Ray Pulses Project at the APS	K. Harkay
16:00	Committee Executive Session	
18:00	Adjourn	
Thursday, November 16, 2006 - Conference Room A5000, Building 401		
08:00	Committee Executive Session	
08:30	Questions/Responses with APS Staff as Needed	
10:00	Committee Report Writing Session (box lunches available)	
13:00	Closeout with APS Management	

Goals and Approach

- Goals:
  - Increase the APS brightness in wide energy range more then one order of magnitude;
  - Compress x-ray pulse to a pcsec level or less.

- Approach:
  - Design and build new storage ring and booster,

    or/and
  - Design and build new injector based on ERL

- Means to achieve goals:
  - Decrease emittance
  - Long straights
  - Special IDs
  - Increase current

Self-Imposed Boundary Conditions

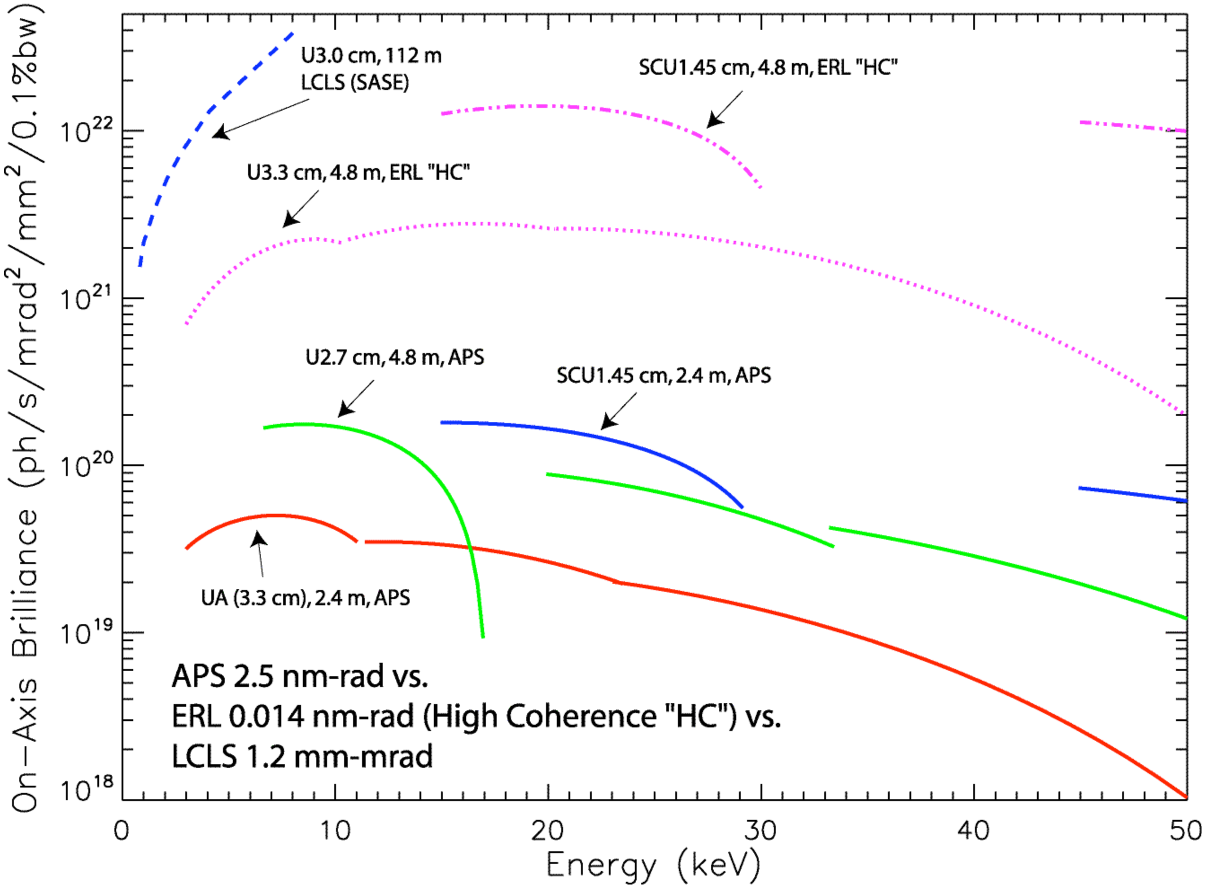
- Utilize the existing APS storage ring tunnel;
- Utilize existing front-ends and ID beamlines;
- Preserve or increase flux in the standard operation mode;
- Preserve the capability of single bunch current up to 16 mA;
- Maintain existing reliability level of all accelerator systems;
- Maintain x-ray beam stability at new, significantly improved level

Approach Options

- Option A – new ERL type injector
  – Full energy linac – outfield option
  – Multipass linac – infield option

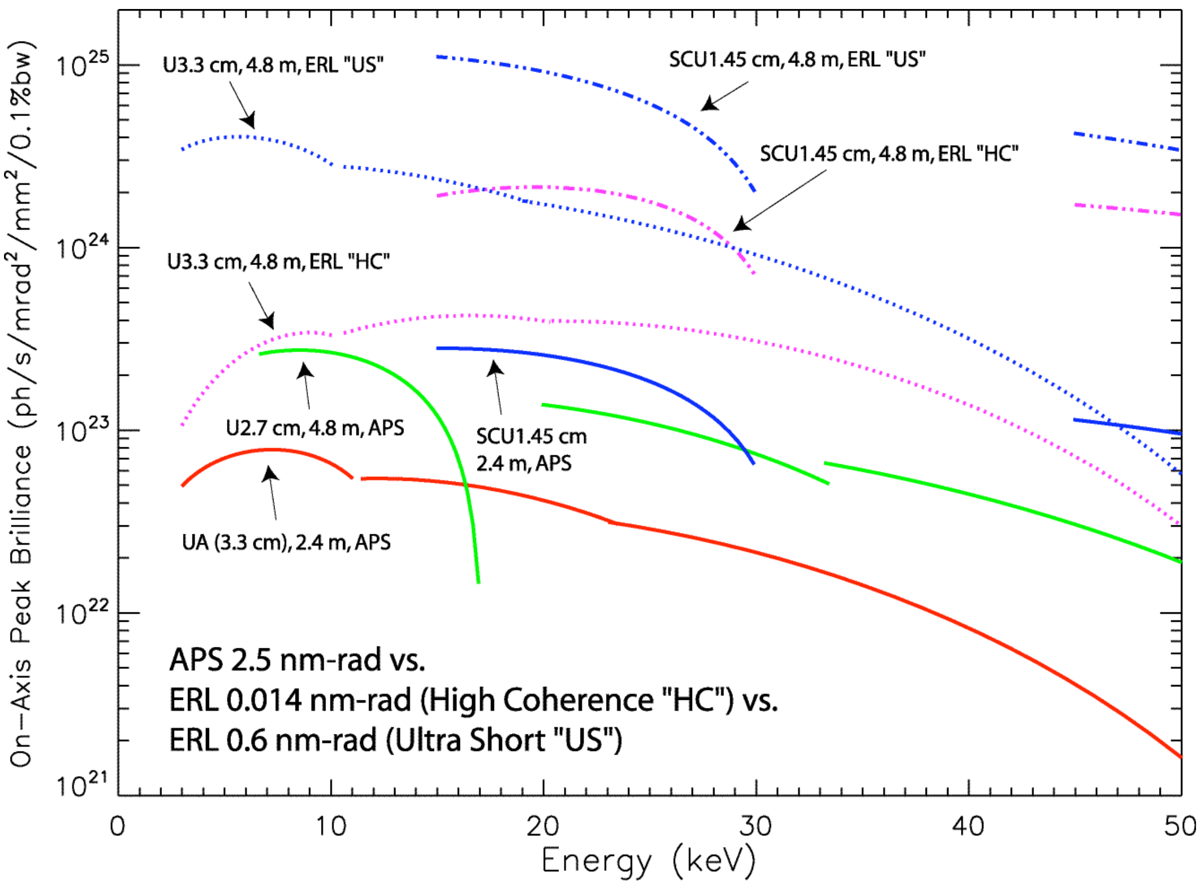
- Option B - new storage ring
  – 1nm storage ring with long straights
  – 1.67 nm storage ring with long straights and extra ID beamlines

On-Axis Brilliance Tuning Curves for Current APS Lattice vs. ERL High Coherence vs. LCLS



- Beam Energy 7.0 GeV (APS), 4.3 – 13.6 GeV (LCLS; Ref. H.-D. Nuhn)
- Beam Current 100 mA (APS), 25 mA (ERL High Coherence "HC")

On-Axis Peak Brilliance Tuning Curves for Current APS Lattice vs. ERL High Coherence & Ultra Short



- Beam Energy 7.0 GeV (APS)
- Peak Current 156 A (APS 2.5 nm-rad), 3.8 A (ERL High Coherence "HC"), 4.0 kA (ERL Ultra Short "US")

An "Infield" Option (Sereno)[1,2]

- Advantages
  - No impact on external environment
  - Multi-pass linac shorter, cheaper
  - Recirculation feature for commissioning
- Disadvantages
  - Complex, crowded beam optics
  - Somewhat higher emittance growth expected[3]
  - No major expansion of beamlines

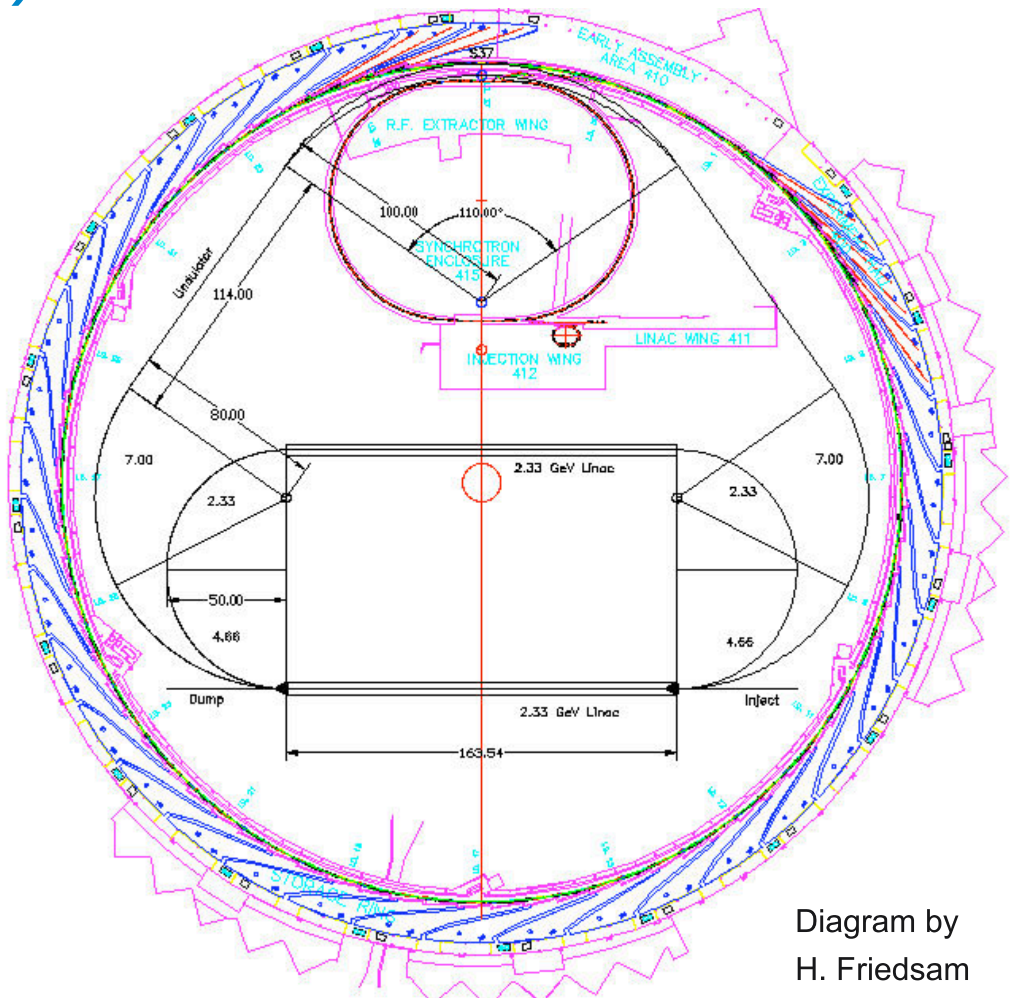


Diagram by H. Friedsam

[1]N. Sereno, "Infield ERL Option," 10/19/06.

[2]Evolved from suggestions by Y. Cho, D. Douglas, R. Gerig, M. White.

[3]V. Sajaev, ASD/APG/2006-20, 8/20/06.

An "Outfield" ERL Option (G. Decker[1])

- Advantages
  - Linac points away from APS[2] to give straight-ahead FEL hall[3]
  - Beam goes first into new, emittance-preserving turn-around arc[4]
  - Avoids wetlands etc. by using narrow corridor for linac and return line
- Issues
  - Big and expensive
  - Turn-around should be *bigger* than shown
  - Beam goes wrong way around the APS in this sketch (readily fixed)
  - No space for really long undulators.

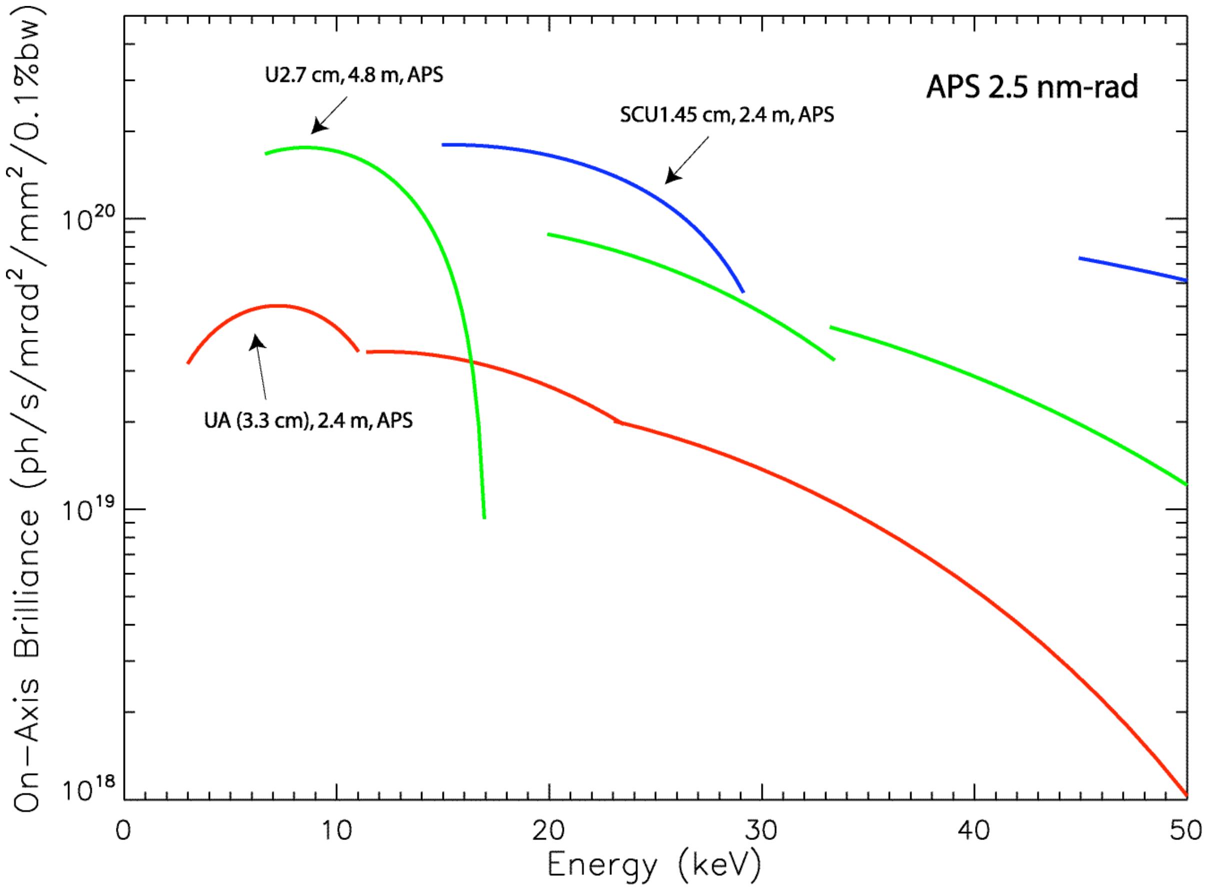
[1]G. Decker, "APS Upgrade External ERL Option," 9/27/06.

[2]M. Borland, "ERL Upgrade Options and Possible Performance," 9/18/06.

[3]M. Borland, "Can APS Compete with the Next Generation?", May 2002.

[4]M. Borland, OAG-TN-2006-031, 8/16/06.

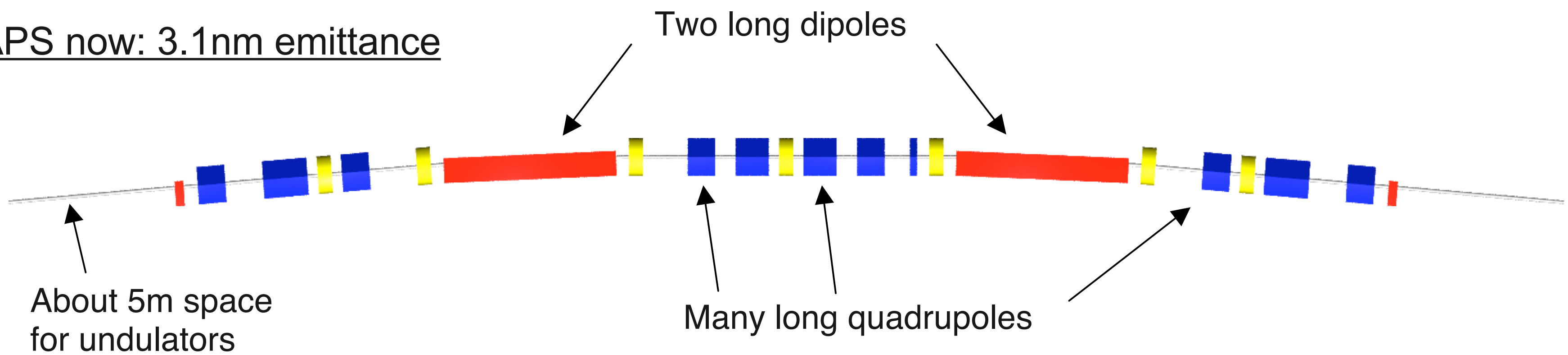
On-Axis Brilliance Tuning Curves for The APS 2.5 nm-rad Lattice



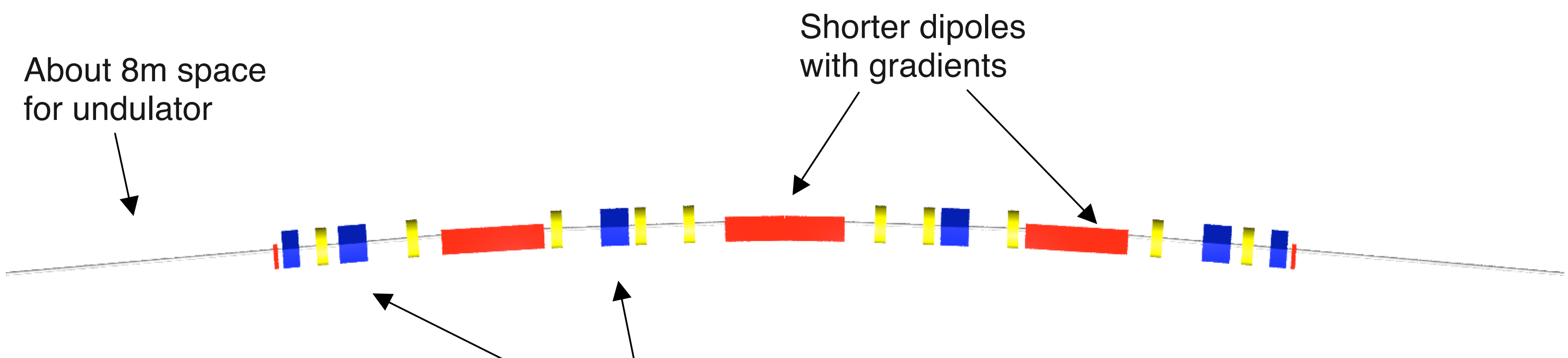
- Beam Energy 7.0 GeV
- Beam Current 100 mA, Coupling 1.0%

Triple-Bend Design (APS1nm)

APS now: 3.1nm emittance



Possible upgrade: 1nm emittance

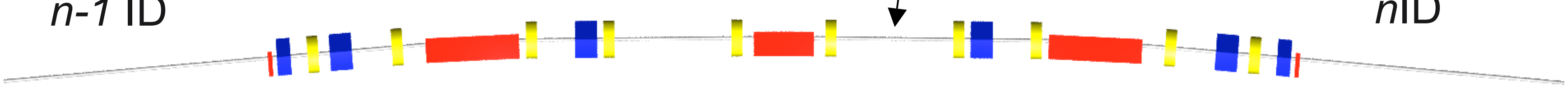


Thanks to L. Emery for help with figures.

Another Option: APSx3

- This is an evolution of the 1nm lattice
- Offers three times as many ID beamlines
- Could provide a three-pole wiggler for beamlines that still want bending-magnet-like source
- Downside: Emittance doesn't improve much

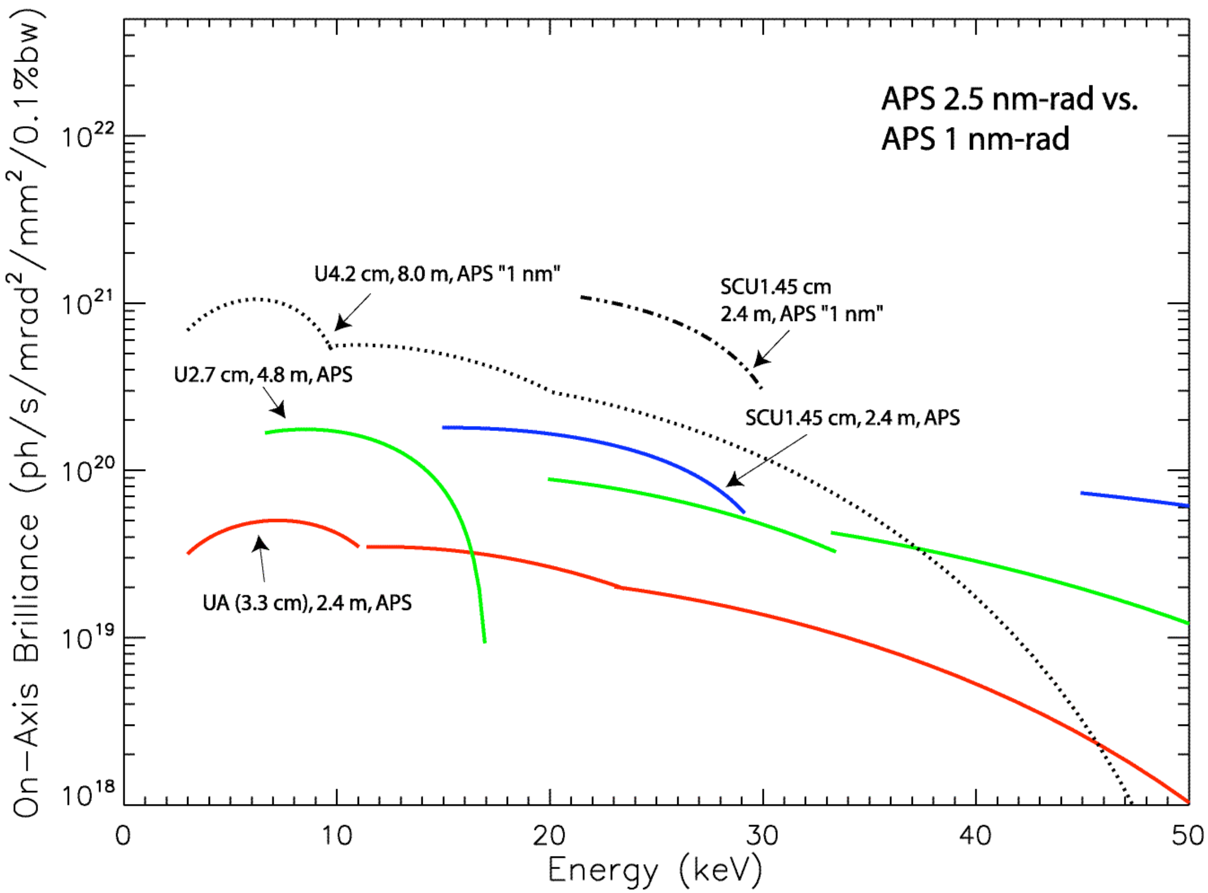
<u>APSx3: ~1.67nm</u>



2.1m magnet-to-magnet
in new straight sections.

Thanks to L. Emery for help with figures.

On-Axis Brilliance Tuning Curves for The APS 1 nm-rad Lattice



- Beam Energy 7.0 GeV
- Beam Current 100 mA (APS), 200 mA (APS 1 nm-rad), Coupling 1.0%

Source Parameters Compared to APS Now

Case	*# of Sectors*	*x rms (microns)*	*x' rms (microrad)*	*y rms (microns)*	*y' rms (microrad)*
Today	40	275	11.4	8.5	3
APS 1nm	40	~120	~10	~7	~1
APSx3	40	~120	~14	~13	~1

- Upgraded ring would run at 200 mA, 7 GeV
- Insertion devices would be customized to, e.g., maximize brightness consistent with power limitations of front ends.

R&D Tasks

ERL specific tasks

- High brightness e-source
- Superconducting RF
- Novel IDs and Front Ends

SR specific tasks

- Electron and x-ray beams diagnostics
- Magnets
- Novel IDs and front-ends

High Brightness e-sources - I

	Operational ERL guns			ERL guns under commission	
Facility	JLab ERL FEL	JAERI ERL	BINP ERL FEL	Daresbury ERLP	Cornell ERL
Gun type	DC	DC	DC	DC	DC
Average current (mA)	10	5	20 ~ 40	6.5	100*
Frequency (booster) (MHz)	1497	499.8	180	1300	1300
Norm. rms emit (μm)	<10	30	32	1.5*	<1*

*Design value

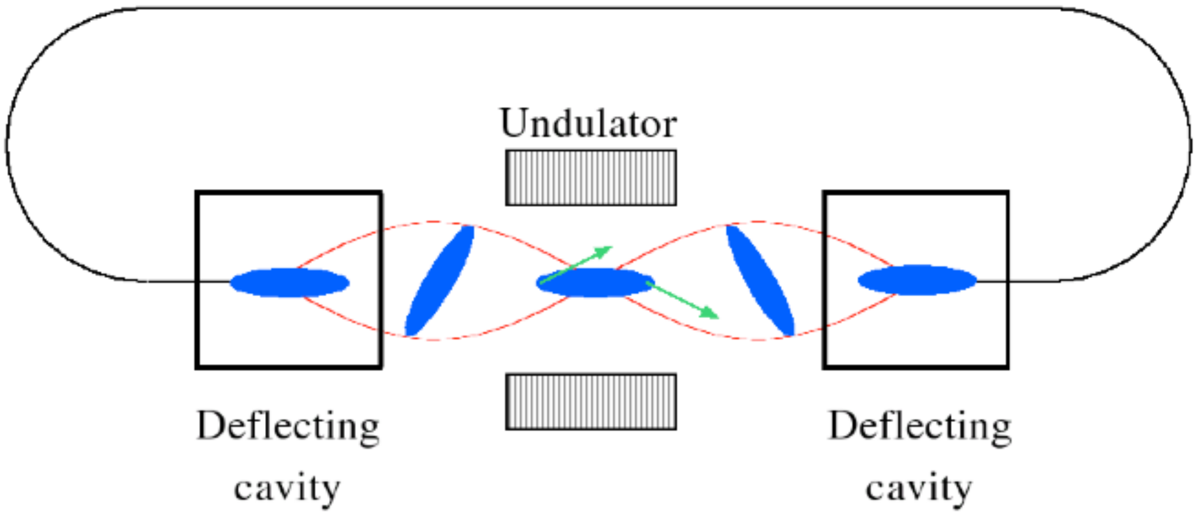
Compiled by Y.-E.Sun

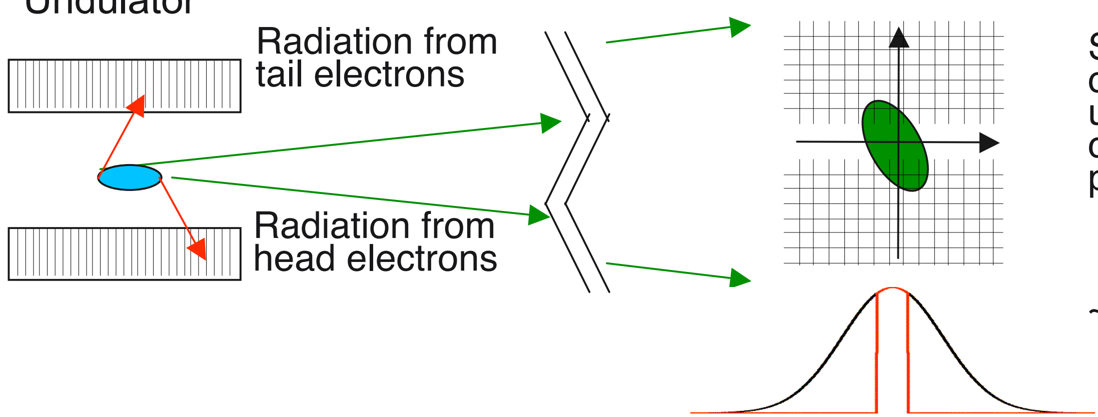
High Brightness e-sources - II

	ERL guns under development			
Facility	Rossendorf, Germany	LANL/AES	BNL/AES	Peking Univ., China
Gun type	SC rf	NC rf	SC rf	DC + SC rf
Frequency (MHz)	1300	700	703.75	1300
Average current (mA)	1	100	500	1.6 -- 5 (0.27 achieved)
Norm. rms emit (μm)	0.5 – 2.5	6	2	3 – 5 (achieved)

Compiled by Y.-E.Sun

Transverse RF Chirp Concept (A.Zholents et.al., NIM A425, 1999)

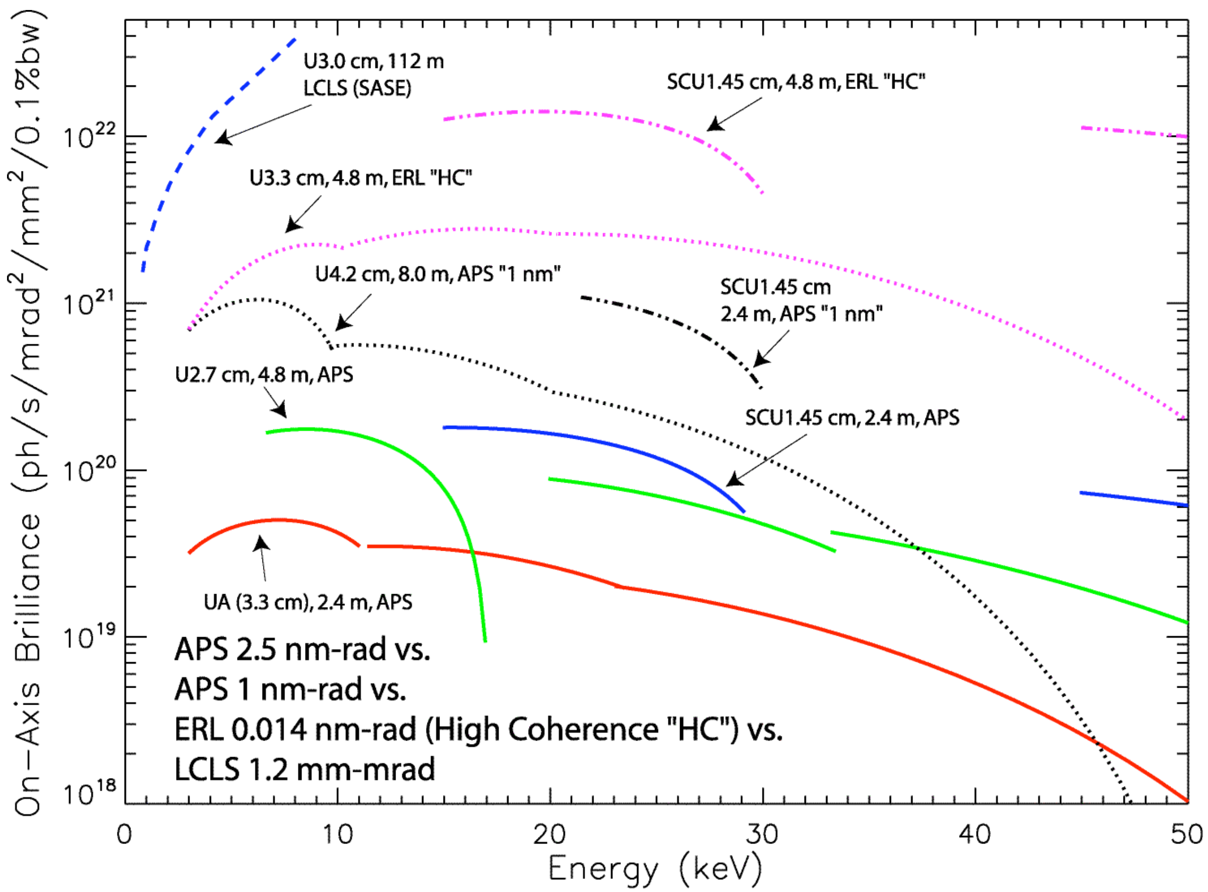




Slits can be used to clip out a short pulse. Can also use asymmetric cut crystal to compress the pulse.

~1 ps FWHM possible for APS

On-Axis Brilliance Tuning Curves for New Options: APS 1 nm-rad vs. ERL High Coherence vs. LCLS



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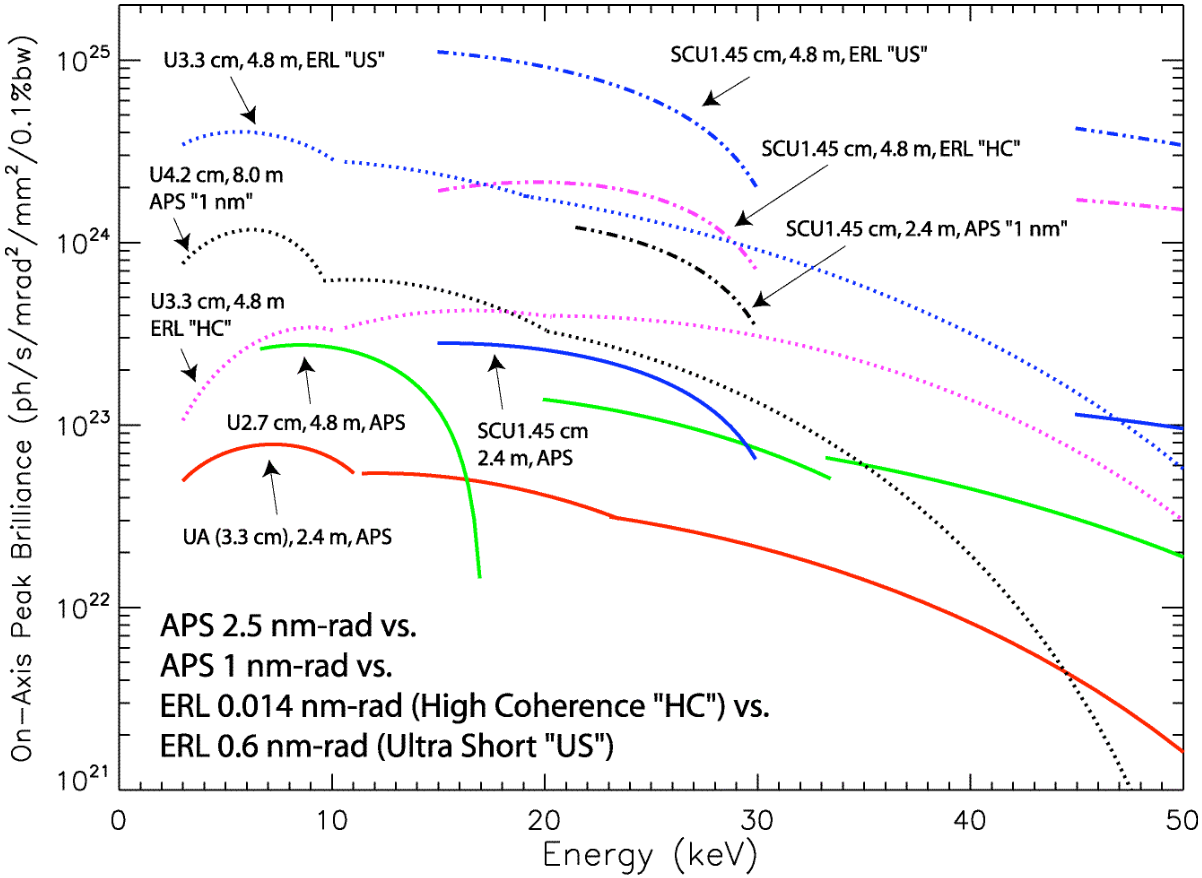
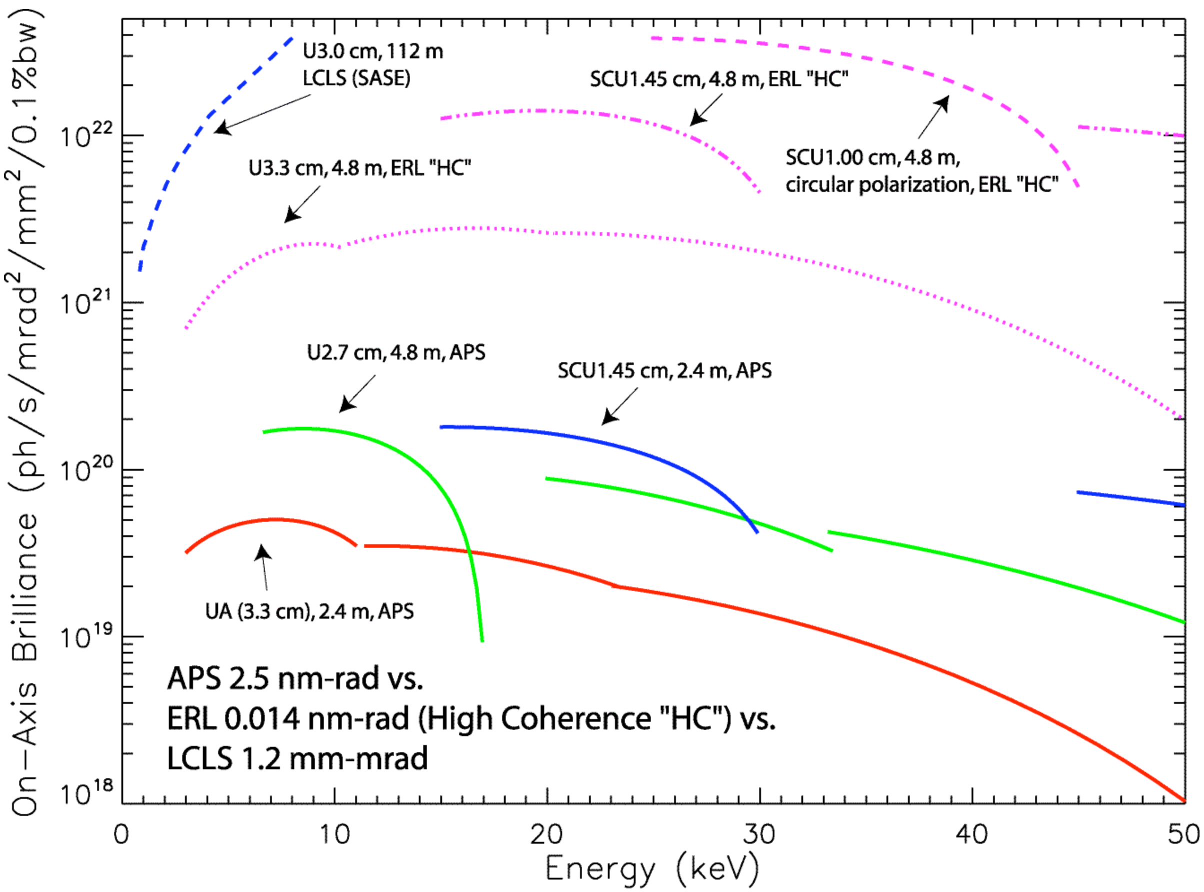
- Beam Current 100 mA (APS), 200 mA (APS 1 nm-rad), 25 mA (ERL High Coherence “HC”)

On-Axis Peak Brilliance Tuning Curves for New Options: APS 1 nm-rad vs. ERL High Coherence & Ultra Short



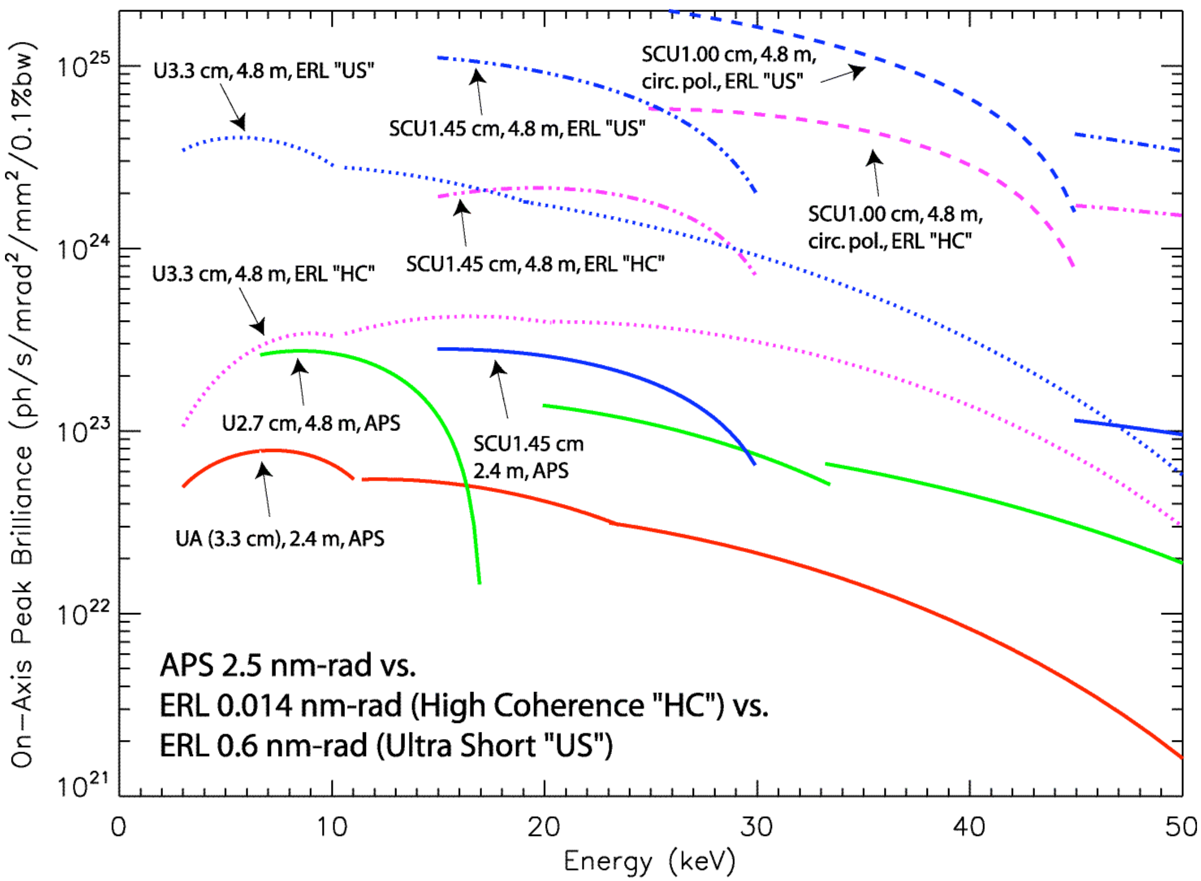
- Beam Energy 7.0 GeV (APS)
- Peak Current 156 A (APS 2.5 nm-rad), 223 A (APS 1 nm-rad), 3.8 A (ERL High Coherence “HC”), 4.0 kA (ERL Ultra Short “US”)

On-Axis Brilliance Tuning Curves for Current APS Lattice vs. ERL High Coherence vs. LCLS



- Beam Energy 7.0 GeV (APS), 4.3 – 13.6 GeV (LCLS; Ref. H.-D. Nuhn)
- Beam Current 100 mA (APS), 25 mA (ERL High Coherence “HC”)

On-Axis *Peak* Brilliance Tuning Curves for Current APS Lattice vs. ERL High Coherence & Ultra Short



- Beam Energy 7.0 GeV (APS)
- Peak Current 156 A (APS 2.5 nm-rad), 3.8 A (ERL High Coherence "HC"), 4.0 kA (ERL Ultra Short "US")

Parameters Summary

	Average Brightness	Peak Brightness	Flux	Emittance Limit	Minimum xray Pulse Length	R&D Challenge	Length of Darktime
	Photons/s/mm^2/ mrad^2/0.1%BW	Photons/s/mm^2/ mrad^2/0.1%BW	photons/s	nm	ps FWHM		
APS today	$5 \cdot 10^{19}$	$8 \cdot 10^{22}$	$8 \cdot 10^{14}$	2.8	1	low	0
Storage Ring Options							
1-nm	$1 \cdot 10^{21}$	$1 \cdot 10^{24}$	$5 \cdot 10^{15}$	0.5	1	Low	>12 months
APS X 3	$6 \cdot 10^{20}$	$6 \cdot 10^{23}$	$5 \cdot 10^{15}$	0.85	1	Low	>12 months
ERL Options							
7 GeV Single Pass Linac	$2 \cdot 10^{21}$	$4 \cdot 10^{24}$	$2 \cdot 10^{15}$	0.004	0.1	High	< 5-6 months
Multipass Linac	$2 \cdot 10^{21}$	$4 \cdot 10^{24}$	$2 \cdot 10^{15}$	0.004	0.1	High	longer if inside SR

Notes:

For multipass-linac, peak brightness may be less depending on CSR in recirculating arcs.

Emittance limit for ERLs is set by quantum excitation (Value for midpoint in APS ring).

For ERL, flux is for the high-flux (100 mA) mode.

For ERL, not all parameters are delivered simultaneously.

Assume ring emittance can be made two-fold less with distributed-dispersion tuning.

Minimum x-ray pulse length for rings assumes use of crab cavities.

Conclusions

- Two different options have been studied
- Main physics (not all) issues have been addressed
- No apparent showstoppers for both options
- ERL option requires challenging accelerator R&D but provides significantly higher gains